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A Review on the Potential Health Risks Associated with Heavy Metal Accumulation in Humans

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ABSTRACT: Heavy metal poisoning (toxicity) is the result of exposure to heavy metals like lead, mercury and arsenic. Heavy metals bind to parts of your cells that prevent your organs from doing their job. Symptoms of heavy metal poisoning can be life threatening and they can cause irreversible damage. Heavy metal poisoning occurs when microscopic molecules of metals accumulate within your body after exposure. Heavy metals attach to your cells and prevent them from performing their functions, which causes symptoms that could be life threatening without treatment.

KEYWORDS: heavy metal , accumulation, humans, health, potential, life threatening, exposure

I.INTRODUCTION

You can get heavy metal poisoning by exposing yourself to heavy metals. Heavy metals form naturally within the Earth's crust. We interact with small amounts of heavy metals every day, like when you check the temperature of your thermometer, which uses mercury. Heavy metal poisoning occurs when metals get into your body. This can happen if you're exposed to a large amount of metal including:[1]

- Eating a lot of food that contains metals (fish).
- Drinking water from older water supply systems.
- Working with metals on the job.
- Taking medications or supplements with high amounts of metallic elements.[2]
- Handling metals or products made with a large amount of metal (like paint or pesticides) without using personal protective equipment.

Most metals that cause poisoning are in a microscopic (molecular) form when they enter your body. They are so small, you won't be able to see them. Heavy metals can enter your body by:[3]

- Absorbing into your skin.
- Breathing in or inhaling tiny metal molecules.[4]
- Eating or drinking (ingesting) the metal from food or water.

Several metals can be toxic to your body.[5] The most common toxic metals are:

Type of metal	Where it can be found
Lead	Contaminated water from lead pipes, batteries, paint, gasoline, construction materials.
Mercury	Liquid in thermometers, lightbulbs, dental amalgam ("silver") fillings, batteries, seafood, topical antiseptics.
Arsenic	Topical creams, herbicides, insecticides, pesticides, fungicides, paints, enamels, glass, contaminated water, seafood, algae.
Cadmium	Cigarette smoke, metal plating, batteries.
Thallium	Rodenticides, pesticides, fireworks.

Heavy metal poisoning can affect anyone who has exposure to heavy metals. This most often affects people who:[6]

- Drink water from pipes made of older metals (lead).
- Work with metals.
- Take more than the prescribed dosage of medicine or supplements that contain metal.
- Live in an environment with high air or water pollution.
- Eat a lot of foods that contain metal.
- Consume a non-edible product made with metal (paint).[7]

Children are at a higher risk of heavy metal poisoning because their bodies are still developing and they are more sensitive to the harmful effects of heavy metals.[8]

The exact rate of occurrence is unknown, but in the United States, heavy metal poisoning is rare since it only affects people who have exposure to heavy metals. The number of people diagnosed with heavy metal poisoning decreased significantly over the last 20 years because of awareness and preventative measures to remove heavy metals from homes.[9] Exposure to heavy metals can be dangerous to your health. While we use and interact with metals every day, certain heavy metals are toxic because the molecules that make up the metal damage or negatively interact with the cells in your body that are essential to keep your organs functioning.[10]

Your body has small amounts of metals in it already, like iron, copper and zinc. These metals are important to keep your organs functioning. If you have too much metal accumulated within your body, it can damage your vital organs like your brain and liver.[11]

The industrial activities of the last century have caused massive increases in human exposure to heavy metals. Mercury, lead, chromium, cadmium, and arsenic have been the most common heavy metals that induced human poisonings. Here, is the mechanistic action of these heavy metals according to the available animal and human studies. Acute or chronic poisonings may occur following exposure through water, air, and food. Bioaccumulation of these heavy metals leads to a diversity of toxic effects on a variety of body tissues and organs.[12] Heavy metals disrupt cellular events including growth, proliferation, differentiation, damage-repairing processes, and apoptosis. Comparison of the mechanisms of action reveals similar pathways for these metals to induce toxicity including ROS generation, weakening of the antioxidant defense, enzyme inactivation, and oxidative stress. On the other hand, some of them have selective binding to specific macromolecules. The interaction of lead with aminolevulinic acid dehydratase and ferrochelatase is within this context. Reactions of other heavy metals with certain proteins were discussed as well.[13] Some toxic metals including chromium, cadmium, and arsenic cause genomic instability. Defects in DNA repair following the induction of oxidative stress and DNA damage by the three metals have been considered as the cause of their carcinogenicity. Even with the current knowledge of hazards of heavy metals, the incidence of poisoning remains considerable and requires preventive and effective treatment. The application of chelation therapy for the management of metal poisoning could be another aspect of heavy metals to be reviewed in the future.[14]

II.DISCUSSION

Heavy metals have harmful effects on human health, and exposure to these metals has been increased by industrial and anthropogenic activities and modern industrialization. Contamination of water and air by toxic metals is an environmental concern and hundreds of millions of people are being affected around the world.[15] Food contamination with heavy metals is another concern for human and animal health. Concentration of heavy metals in water resources, air, and food is assessed with this regard . Metals among the other environmental pollutants may also occur naturally and remain in the environment. Hence, human exposure to metals is inevitable, and some studies have reported gender differences in the toxicity of metals [16].They may frequently react with biological systems by losing one or more electrons and forming metal cations which have affinity to the nucleophilic sites of vital macromolecules. Several acute and chronic toxic effects of heavy metals affect different body organs. Gastrointestinal and kidney dysfunction, nervous system disorders, skin lesions, vascular damage, immune system dysfunction, birth defects, and cancer are examples of the complications of heavy metals toxic effects. Simultaneous exposure to two or more metals may have cumulative effects . High-dose heavy metals exposure, particularly mercury and lead, may induce severe complications such as abdominal colic pain, bloody diarrhea, and kidney failure .On the other hand, low-dose exposure is a subtle and hidden threat, unless repeated regularly, which may then be diagnosed by its complications, e.g., neuropsychiatric disorders including fatigue, anxiety, and detrimental impacts on intelligence quotient (IQ) and intellectual function in children[17] . The fact that several metals have emerged as human carcinogens is another important aspect of the chronic exposure. While the exact mechanism is unclear, aberrant changes in genome and gene expression are suggested as an underlying process. Carcinogenic metals such as arsenic, cadmium, and chromium can disrupt DNA synthesis and repair .The toxicity and carcinogenicity of heavy metals are dose dependent. High-dose exposure leads to sever responses in animal

and human which causes more DNA [18]damage and neuropsychiatric disorders . The toxic mechanism of heavy metals functions in similar pathways usually via reactive oxygen species (ROS) generation, enzyme inactivation, and suppression of the antioxidant defense. However, some of them cause toxicities in a particular pattern and bind selectively to specific macromolecules. Different toxic mechanisms of heavy metals increase our knowledge on their harmful effects on the body organs, leading to better management of animal and human poisonings.[19] We aimed to review the literature on the toxicity mechanisms associated with heavy metals, which will increase our knowledge on their toxic effects on the body organs, leading to better management of the metal poisonings.

Mercury (Hg) is found in air, water, and soil and exists in three forms: elemental or metallic mercury (Hg0), inorganic mercury (Hg+, Hg2+), and organic mercury (commonly methyl or ethyl mercury) . Elemental mercury is liquid at room temperature and can be readily evaporated to produce vapor. Mercury vapor is more hazardous than the liquid form. Container breakage causes Hg0 spills and inhaling large amounts of Hg vapor can be fatal. Organic mercury compounds such as methyl mercury (Me-Hg) or ethyl mercury (Et-Hg) are more toxic than the inorganic compounds. The order of increasing toxicity related to different forms of mercury is defined as Hg0 < Hg2+, Hg+ < CH3-Hg.Mercury compounds have many applications in mining for example extraction of gold and some industrial processes. In lamp producing factories, [20]Hg is used in the production of fluorescent light bulbs. Me-Hg and Et-Hg have been used as fungicides to protect plants against infections. Moreover, mercury has had medicinal uses in the past, but such drugs have been replaced by safer pharmaceutical medicines. Some examples are chlormerodrin, merbaphen, and mercurophylline[21] (all diuretics) and phenylmercury nitrate (disinfectant). Besides, some skin lightening creams and some soaps are mercury polluted. Mercury chloride (HgCl2) is one of the active ingredients of skin brightening creams which are used to remove freckles and spots of the skin due to excessive accumulation of melanin. HgCl2 inhibits tyrosinase activity irreversibly, an enzyme which functions in melanin formation, by replacing the copper cofactor.Further, a mercury-containing organic compound called thimerosal has been used as a preservative in multidose vials of vaccines. Hg0 (vapor) is readily absorbed from lungs (80%) and distributed throughout the body. Hg0 can pass the blood brain barrier (BBB) and placenta; thus, its neurotoxicity is higher than inorganic Hg which passes through membranes at a slower rate. Hg0 is oxidized in the body to produce divalent Hg (Hg2+). Hg0 (liquid) is slightly absorbed from the gastrointestinal (GI) tract and does not appear to be toxic. Inorganic Hg is concentrated in the kidneys—reabsorbed from proximal tubules as Cys-S-Hg-S-Cys or basolateral membrane by organic anions transporters. Inorganic Hg cannot pass the BBB and placenta.[22] Organic Hg is easily absorbed from the GI tract (95%) and distributed throughout the body. CH3-Hg is bound to thiol-containing molecules such as cysteine (CH3-Hg-Cys) so that it can pass the BBB. Hair is considered as an index of Hg exposure since CH3-Hg is accumulated there. Other than hair, Hg is excreted in urine and feces. CH3CH2-Hg follows similar pharmacokinetics to CH3-Hg[23] .

III.RESULTS

Lead is a harmful environmental pollutant which has high toxic effects to many body organs. Even though Pb can be absorbed from the skin, it is mostly absorbed from respiratory and digestive systems. Pb exposure can induce neurological, respiratory, urinary, and cardiovascular disorders due to immune-modulation, oxidative, and inflammatory mechanisms.[24] Furthermore, Pb could disturb the balance of the oxidant–antioxidant system and induce inflammatory responses in various organs. Exposure to Pb can produce alteration in physiological functions of the body and is associated with many diseases . Pb is highly toxic which has adverse effects on the neurological, biological, and cognitive functions in the bodies. The international level-of-concern for Pb poisoning is 10 µg/dl in the blood .Adulteration of opium with Pb has been considered as a threat to human health in recent years . Chromium (Cr) is found in the earth's crust and seawater and is a naturally occurring heavy metal in industrial processes .Cr has multiple oxidation states ranging from −2 to + 6[25], in which the trivalent and hexavalent forms are the most common stable forms .Cr (VI) is related to a series of diseases and pathologies while Cr (III) is required in trace amounts for natural lipid and protein metabolism and also as a cofactor for insulin action . Based on the International Agency for Research on Cancer (IARC) report hexavalent chromium has been classified as a group I occupational carcinogen .In this context, a meta-analysis of 973,697 workers involving 17 standardized incidence ratios (SIRs) from seven countries and four kinds of occupations found that 11,564 of them had cancer .The primary route of exposure for nonoccupational human populations occurs via ingestion of chromium containing food and water or dermal contact with products containing chromium[26] . Furthermore, metallurgical, refractory, and chemical industries release a large amount of Cr into soil, ground water, and air which causes health issues in humans, animals, and marine life . Cr can cause a variety of diseases through bioaccumulation in human body. This ranges from dermal, renal, neurological, and GI diseases to the development of several cancers including lungs, larynx, bladder, kidneys, testicles, bone, and thyroid[27] .

Cadmium (Cd), although rare, occurs naturally in soil and minerals such as sulfide, sulfate, carbonate, chloride, and hydroxide salts as well as in water. High levels of Cd in water, air, and soil can occur following industrial activities

which could be a substantial human exposure to Cd. Moreover, the ingestion of contaminated food will cause major exposure to Cd.[28] Cd exposure may also occur through smoking, which is capable of elevating blood and urine Cd concentrations. Presence of Cd in contaminated water could disturb the necessary mechanisms in the body, possibly resulting in short-term or long-term disorders . Cd is classified by the International Agency for Research on Cancer (IARC) as carcinogenic to humans . [29]Occupational exposure to Cd may occur in alloy, battery, and glass production and in electroplating industries. Due to the importance of the subject, Cd level in the air is routinely monitored in some countries . Rice, grains, and sea food have been found to be polluted by Cd ; nonetheless, after oral intake, a small portion of Cd is absorbed.[30] Tragically, the outbreak of Itai-itai disease in Japan was due to the mass Cd contamination of food and water supplies. The patients suffered from painful degenerative bone disease, kidney failure, and the GI and lungs diseases .Unlike low GI absorption, Cd is more efficiently taken from the lungs via industrial dust. Acute or chronic inhalation of Cd in industrial areas might lead to renal tubular dysfunction and lung injuries. Cd blood concentration in smokers is almost twice higher than that of nonsmokers. Researchers found Cd blood levels of 0.4 against 1.3 µg/L for nonsmokers vs. smokers in adult population . This seems to be related to the nature of tobacco plants to accumulate relatively high Cd concentrations in tissues especially in the leaves .[31]

Arsenic as a harmful heavy metal is one of the main risk factors for the public health. Sources of As exposure are occupational or via the contaminated food and water. [32]As has a long history of use, either as a metalloid substance or as a medicinal product. It is notoriously known as the king of poisons and poison of kings .As is present as a contaminant in food, water, and environment. Arsenic exists in the forms of metalloid (As0), inorganic (As3+ and As5+), organic, and arsine (AsH3). The order of increasing toxicity of As compounds is defined as organic arsenicals < As0 < inorganic species (As5+ < As3+) < arsine Primary As absorption is from the small intestine. Other routes of exposure are from the skin contact and by inhalation. Following distribution to many tissues and organs in the body including the lungs, heart, kidneys, liver, muscles, and neural tissue,[33] As is metabolized to monomethylarsonic acid (MMA) and dimethylarsinic acid (DMA) in which the latter is the predominant form in the urinary excretion of As . Acute and chronic As toxicity is related to the dysfunctions of numerous vital enzymes. Similar to the other heavy metals, As can inhibit sulfhydryl group containing enzymes which leads to their dysfunction. Moreover, As inhibits the pyruvate dehydrogenase by binding to the lipoic acid moiety of the enzyme. Pyruvate dehydrogenase inactivation can block the Krebs cycle[34] and inhibits oxidative phosphorylation. As a result, ATP production decreases, resulting in cell damage . Furthermore, the damage of capillary endothelium by As increases vascular permeability, leading to vasodilation and circulatory collapse[35] .

IV.CONCLUSIONS

The heavy metals enter the body from different ways including drinking water, air, food, or occasionally dermal exposure. Following absorption, heavy metals are retained, and they accumulate in the human body. Bioaccumulation of toxic metals leads to a diversity of toxic effects on a variety of body tissues and organs. Metal toxicity can have acute or chronic manifestations. Heavy metals disrupt cellular events including growth, proliferation, differentiation, damage-repairing processes, and apoptosis. Toxic metals can also promote epigenetic alterations which can influence gene expression. Comparison of the mechanisms of action reveals similar pathways[36] for these metals to induce toxicity including ROS generation, weakening of the antioxidant defense, enzyme inactivation, and oxidative stress. On the other hand, some researches have shown that the metals selectively bind to specific macromolecules. The interaction of Pb with ALAD and ferrochelatase is within this context. Reactions of other heavy metals with certain proteins were discussed as well. Some toxic metals including Cr, Cd, and As cause genomic instability. Defects in DNA repair following the induction of oxidative stress and DNA damage by these metals is considered as the cause of their carcinogenicity.[37] The application of chelation therapy for the management of metal poisoning has not been reviewed here. This could be another aspect of heavy metals to be reviewed in the future. Developing specific biomarkers for monitoring heavy metals will be a major achievement in the field. Future research will benefit from the evaluation of new targets as protective procedures against organ toxicity induced by heavy metals.[38]

REFERENCES

1. Emsley 2011, pp. 288, 374
2. ^ Pourret, Olivier; Bollinger, Jean-Claude; Hursthouse, Andrew (2016). "Heavy metal: a misused term?" (PDF). Acta Geochemica. 40 (3): 466–471. doi:10.1007/s11631-021-00468-0. S2CID 232342843.
3. ^ Duffus 2002, p. 798
4. ^ Rand, Wells & McCarty 1995, p. 23
5. ^ Baldwin & Marshall 1999, p. 267
6. ^ Lyman 2003, p. 452

7. ^ The United States Pharmacopeia 1985, p. 1189
8. ^ Raghuram, Soma Raju & Sriramulu 2010, p. 15
9. ^ Thorne & Roberts 1943, p. 534
10. ^ Hawkes 1997
11. ^ Nieboer & Richardson 1980, p. 4
12. ^ Emsley 2011
13. ^ Hoffman, Lee & Pershina 2011, pp. 1691, 1723; Bonchev & Kamenska 1981, p. 1182
14. ^ Silva 2010, pp. 1628, 1635, 1639, 1644
15. ^ Fournier 1976, p. 243
16. ^ Vernon 2013, p. 1703
17. ^ Morris 1992, p. 1001
18. ^ Gorbachev, Zamyatnin & Lbov 1980, p. 5
19. ^ Duffus 2002, p. 797
20. ^ Liens 2010, p. 1415
21. ^ Longo 1974, p. 683
22. ^ Tomasik & Ratajewicz 1985, p. 433
23. ^ Herron 2000, p. 511
24. ^ Nathans 1963, p. 265
25. ^ Topp 1965, p. 106: Schweitzer & Pesterfield 2010, p. 284
26. ^ King 1995, p. 297; Mellor 1924, p. 628
27. ^ Cotton 2006, p. 66
28. ^ Albutt & Dell 1963, p. 1796
29. ^ Wiberg 2001, pp. 1722–1723
30. ^ Wiberg 2001, p. 1724
31. ^ Edelstein et al. 2010, p. 1796
32. ^ Haynes 2015, pp. 4–95
33. ^ Weart 1983, p. 94
34. ^ Deschlag 2011, p. 226
35. ^ Wulfsberg 2000, pp. 209–211
36. ^ Ahrland, Liljenzin & Rydberg 1973, p. 478
37. ^ Korenman 1959, p. 1368
38. ^ Yang, Jolly & O'Keefe 1977, p. 2980; Wiberg 2001, pp. 592; Kolthoff & Elving 1964, p. 529